capillary tube to a feeler bulb fastened to the suction line from the evaporator. The bulb, bellows, and tube are usually charged with the same liquid refrigerant used in the evaporator itself. A starved condition in the evaporator results in a greater superheat in the gas leaving the evaporator, and this in turn operates through the power element to increase the flow of liquid refrigerant. A flooded evaporator reduces the discharge superheat, and thus tends to reduce the flow of liquid refrigerant. Such an expansion valve is satisfactory for operation with fluctuating loads since this type of control tends to keep the evaporator filled with refrigerant at all times.

*Low-Side Float Valves.* A liquid refrigerant control of the low-side float valve type consists of a ball float located in either a receiver or the evaporator itself on the low pressure side of the system. A needle valve, operated through a simple lever mechanism attached to the float, permits the passage of more or less refrigerant, as the level in the receiver or the evaporator fluctuates. Such a control must be used in conjunction with a flooded evaporator, and has been applied extensively to household refrigerators and, to some extent, in commercial and industrial installations.

*High-Side Float Valves.* A high-side float valve differs from a low-side float valve in that the float is located in a receiver or container on the high pressure side of the system. Proper operation again depends upon metering of the refrigerant through a controlled opening, depending upon the level of the liquid refrigerant in the container. Such a control has the disadvantage that the evaporator must be placed directly adjacent to the float container, or some intermediate pressure device must be applied to prevent flashing of the refrigerant upon pressure drop.

*Capillary Tubes.* A capillary tube may be used as a liquid refrigerant expanding device. Such a device consists of an extremely small bore tube (in the order of 0.04 inch in diameter) of five to twenty feet in length. Although such a restricting device operates as a very simple means of expanding the liquid refrigerant, it has the disadvantage that no modifications are possible to adjust the rate of expansion under various operating conditions. The bore and length of the tube, as well as the proportions of the rest of the system, are critical. It is for these reasons that its application has been limited to factory assembled domestic and commercial units.

## Refrigerant Flow Control

The capacity of the refrigeration system must be controlled in accordance with the load imposed on the system. Except for those cases where the compressor is started and stopped by a thermostat responding to load conditions, some form of control of the refrigerant flow is usually required. Controlling the flow of refrigerant in accordance with the load may be accomplished in a number of ways, some of which are:

1. *Solenoid valves* are frequently used for control of gas or liquid flow. A solenoid valve is placed in the liquid line ahead of the expansion valve. It is closed whenever the compressor is not in operation and thus leakage into the evaporator is prevented. In most cases it is controlled by a thermostat responding to the load. Solenoid liquid valves are widely used for control of refrigerant flow to individual evaporators in a multiple evaporator system operated by one compressor. The compressor capacity is controlled separately by a controller responding to suction pressure. Solenoid liquid and suction valves are sometimes used to isolate an evaporator completely for defrosting purposes.

When solenoid liquid valves are used for controlling refrigerant flow, a *pump-down cycle* of control is often employed. The thermostat closes the solenoid liquid valve and the compressor then pumps down until stopped by the low suction pressure switch. The compressor cannot restart until the thermostat again opens the solenoid liquid valve.

2. *Expansion Valve Modulation.* This form of flow control utilizes the throttling characteristics of the expansion valve to starve the coil under reduced load conditions. This may be accomplished by a device attached to the expansion valve or a pilot control which varies the setting of the expansion valve by changing the pressure in the equalizer line. Either of these are actuated by a controller measuring load conditions and the compressor capacity control is from suction pressure. Since short-cycling of the compressor is apt to occur if the flow of refrigerant is reduced too much, some limit to prevent this is required.

3. *Evaporator Pressure Control* is accomplished by back pressure valves. These are placed in the suction line between the evaporator and the compressor, and maintain the evaporator pressure constant by regulating the amount of vapor drawn from the evaporator. The compressor capacity is controlled from suction pressure at the compressor. The use of back pressure valves permits a lower pressure at the compressor than would be permissible at the evaporator, thus minimizing short-cycling. On a multiple evaporator system served by one compressor, the evaporators may be maintained at different temperatures. Back pressure valves can be equipped with an air connection for automatically varying the evaporator pressure in accordance with the demands of a pneumatic controller. Means for mechanically readjusting the valves by use of a proportioning electric operator also are available.



## Condenser Control

The majority of refrigeration systems, other than fractional horsepower, use water cooled rather than air cooled condensers. Condenser control is used for the purpose of conserving water or limiting the condenser pressure, or both. Solenoid water valves on small compressors or pneumatic or electric valves on larger compressors are usually controlled simultaneously with starting or stopping of the compressor. A pressure operated valve will provide proportional control of water flow in response to condenser pressure. Similar water valves controlled thermostatically by the temperature of water discharged from the condenser are sometimes used. Evaporative condensers may be controlled by an automatic damper responding to a condenser pressure controller. Cooling tower fans sometimes are started and stopped by a thermostat in the condensing water or a pressure controller in the condenser. Some form of freeze protection for evaporative condensers and cooling towers is necessary if they are required to operate in cold weather.

## Refrigeration Control for Air Conditioning Equipment

When refrigerating equipment is used for space cooling, two major control problems exist: one is control of the temperature and the other, control of the humidity. In some applications the amount of latent heat to be removed is small compared with the sensible heat. In such cases, sufficient dehumidification will usually occur without any special provisions. In other cases, such as theaters, where the latent load is relatively high, the air must be cooled below its dew-point temperature, and sometimes rewarmed to return it to the comfort range. Refer to Chapter 38 for general information on the subject of controls and for applications relating to air conditioning systems.

# REFRIGERATION PIPING

The pressure drop which occurs during passage of the refrigerant through connecting piping is similar in effect to that which occurs through suction and discharge valves of the compressor. Thus, the effect of the pressure drop in the suction line between evaporator and compressor requires that a lower pressure be maintained inside the compressor during suction than is maintained in the evaporator. The pressure drop through the connecting piping between the compressor and the condenser requires that a higher pressure be maintained inside the compressor during discharge than in the condenser. These losses result in a greater compression ratio, and therefore greater power requirements, as well as a lower volumetric efficiency and higher displacement requirements. Pressure losses in the liquid line between condenser or receiver and the expansion valve may result in some flashing of the liquid refrigerant, unless the liquid is subcooled. In all cases, frictional losses should be kept to a minimum, and piping should be selected which will give the smallest loss consistent with overall economy in the system.

Refrigerant liquid lines from the receiver to the expansion valve should